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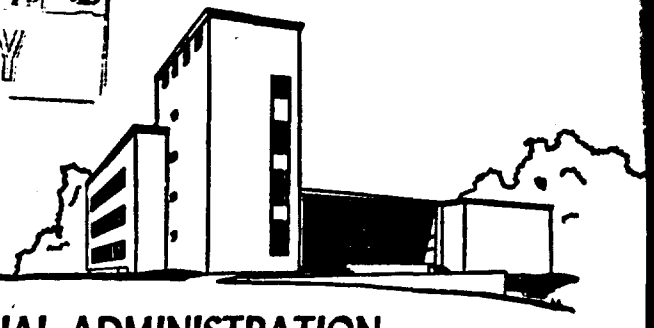

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PROPOSED RESEARCH ON MANAGEMENT INFORMATION SYSTEMS

by

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Introduction

This report is not intended as a survey of ongoing research in the area of "information systems"--although such projects will be alluded to occasionally. It is an outline of some areas in which research seems necessary and a statement of research activity which the authors and their associates plan to follow. This research is detailed below and is based upon preliminary investigations which indicate the feasibility of certain approaches to information system problems. The prelininary work has revealed many areas in which knowledge is virtually non-existent--and areas which are of increasing importance to management. The cost of this lack of knowledge is one of foregone opportunities--of lost profit and of unnecessary expense.

In order to provide a focus in this report which avoids proliferation of examples and terminology, we have concentrated our attention on management information systems in connection with their use in managerial decision making. We have tended also to emphasize areas in which current and readily foreseeable developments in computer technology have made the research problems more apparent. This is not to imply, however, that the research is oriented toward the application of specific computers currently available. Rather, it is based on the assumption that a sophistication in "hardware" production far exceeds sophistication in its use.

The term "information system" has been used in the past in a

variety of connotations. It has been used to describe a multitude of electronic data processing equipment or devices, data collection systems, or even clerical arrangements. The research described here defines an information system as:

> The combination of human and computer-based capital resources which results in the collection, storage, retrieval, communication, and use of data for the purpose of efficient management (planning, decision-making, reporting, and control) of operations in organizations.

It is not necessary, at this point, to discuss precise meanings attached to the functions of organizations. It is important, however, to distinguish between data and information within the context of management information systems.

Data are, in one sense, "facts", which can take a variety of forms. They are the raw materials--the reports or images of the activities of an organization--which are collected and stored. Information is the intelligence of data within context. That is, it is the output resulting from the conversion of raw data into a "product" which enables managers to take action appropriate within a particular frame of reference. For example, an item of data may become information when provided in response to a particular question which facilitates the execution of a decision. An information system, therefore, must include not only the means for gathering, storing, and retrieving data, but also the means for converting these "inputs" into information for managerial use.

Recent Computer Developments and the Increasing Need for Research On Information Systems

Thus far, we have confined our remarks to information systems in a general sense rather than with specific reference to computer-based systems. While information systems exist in the absence of computers, the presence of the computer has made possible the notion that a system could be developed which provides an all-inclusive network for collecting, storing, and processing company-wide data. For example, the popular phrase "total information system" refers to a system whose basic characteristics include: a very large data base, such as 10^{10} characters providing millions of records; multiple user access and information requirements; parallel and multiprogrammed data processing; and centralized organization. Because of the multiplicity of users and large volumes of data handled within these systems, complex problems in systems design arise in areas, such as data coding, file organization and maintenance, planning equipment and programming requirements, and the like.

The role of technological advance in creating research problems is not, however, limited to total information system operations. The problems of decision-making and control in response to new information inputs also have become increasingly complicated. This is particularly evident in the "latest generation" of computers which possess the additional capability of the collection and processing of data in "real time." By "real time" data collection we refer to the instantaneous (or practically instantaneous) recording of events as they occur.

The simple statement that it is the use to which these immense capabilities are put rather than their existence which determines value, seems frequently ignored. For example, a survey recently conducted among its executives by a large progressive and computer-sophisticated company as part of the planning for installation of a real-time total information system, indicated that the executives wanted the same information they had been previously receiving but wanted it more promptly. In other words, the system was perceived as a device to be used primarily for obtaining data and reports previously provided but in a more "timely" fashion. Until such data are translated into management decisions, of course, it is impossible to determine whether or not the existence of more "timely" data has actually improved the decision process.[1/]

We are not suggesting that this survey or other phenomena, incidents which may be observed in actual situations and which indicate that computer capabilities are not fully utilized, indicate a lack of sophistication on the part of the organizations who generate these systems. Rather, it indicates a lack of research or store of knowledge on which to draw in order to utilize computer technology appropriately.

In the remainder of this paper, we have outlined some directions of research which, we believe, will serve to provide much of the requisite

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1/ At the simplest level, the shortening of response time lags may lead to system instability, as may be seen in elementary treatments of servo-mechanical control systems.

fundamental knowledge. The proposed research encompasses several aspects of the problems of translating "data" into "information" with particular focus on the problems which have emerged from technological innovations in computer capability. In particular, the areas of research include:

(1) a more precise description of management operating systems which are multiple-process (i.e., which service several functional operations simultaneously, such as financial, marketing and production management, etc.) by developing mathematical models of such systems;

(2) the development of processes for real time control systems in organizations which are based on decision rules obtained by algorithmic and heuristic methods;

(3) investigation of the man-machine interactions involved in the development of information systems with particular emphasis on the effects of computerized information on human decision making;

(4) examination of the effect of computer based information systems on organization structure, such as on the control of organizational activities which formerly had been controlled by interrelations between human beings;

(5) the relationship between information economics and computer engineering technology in the development of large scale data processing systems;

and (6) the incorporation of the above research into a prescriptive

program for the design of management information systems in the future.

Detailed descriptions of the research proposed under these general categories follow. It should be recognized, however, that each of these programs represents a long-term effort--none represents a specific "problem" nor anticipates immediate solutions. The research planned is interdisciplineary, drawing upon mathematics, economics, psychology, sociology, management science, and various areas in the physical sciences and engineering. It is expected that the research undertaken will contribute, not only to knowledge of information systems, but also to knowledge in the underlying disciplines.

I. Mathematical Models of Multiple-Process Management Operating Systems

During recent years there has been an increased availability of packaged computer program applications from equipment manufacturers and computer user groups. While these systems can provide comparative economies in initial programming development, they do not eliminate the need for analysis of the provided systems and snythesis by potential user organizations. In fact, when the organization requires multiple operating system programs, the necessity for a thorough delineation of system objectives becomes even more critical given the availability of packaged application sub-routines.

Operations research analyses of multiple-process management operating systems to date have provided limited insight into necessary criteria for

system design and the effective integration of varied operating systems within an organization.[1/] The purpose of our proposed research in this context will be:

(1) to explore and compare the effectiveness of various mathematical models which have been employed to describe multiple-process operating systems and to relate these models to an existing system (or several);

(2) to highlight data processing and information system problems which are peculiar to multiple-process operations; and

(3) to develop sufficiently precise descriptions which can be used in prescriptive design criteria for multiple-process management systems.

II. Decision Rules for Real-Time Control

The development of information systems which can collect and process data as rapidly as they are generated (for all practical purposes) poses problems of a kind not heretofore envisioned in management decision-making. Optimal planning schemes - e.g., inventory control models, programming models - assume, with few exceptions,[2/] that decisions are

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1/ A review of previous mathematical research on information systems can be found in Kriebel [15]. An example of exploratory research in modeling multiple-process operating systems is available in Bonini [2].

2/ See Charnes and Cooper [3] and [4] for important exceptions and further suggestions as to the direction in which proposed research in this area will take.

made in advance with all required information initially specified, at least in stochastic form. With substantial time lags between the actual implementation of a plan and the availability of information which could be used to alter the plan, both the wisdom and practicability of significant alteration between planning periods may be questioned. In fact, the time between planning periods is generally determined by the length of the information lag. With no effective time lag, the decision as to whether or not to adjust the plan and if so, how, becomes relevant. This is essentially the problem of control of the decision-making process between planning periods. For the purpose of making full use of real-time capability, this control process must be quantified and programmable.

To this end, we propose a series of investigations into:

(1) establishment of "threshold" levels of information change which necessitate adjustment of the plan;

(2) description of the "posture" which the organization will be in subsequent to an adjustment;

(3) development of optimal adjustment techniques subject to constraints imposed by the desired posture;

(4) development of planning techniques which take into account the later need for adjustment - i.e., the introduction of certain kinds of slack in the plan which reduce the number of adjustment dislocations.

Some work has been done in this area relevant to ballistics.[1/] Management-related investigations in the published literature are virtually non-existent, however. Extension of research by Charnes and Stedry [7] in these problems constitutes part of this program. The work is also an extension of earlier work by these authors in the design of optimal control schemes in the presence of multiple objectives ([5], [6], and [7]).

III. The Impact of Information Systems Technology on Human Decision Making

Little is known about the effect of information feedback on human behavior in a general theoretical sense and less in the specific context of computerized information flow. Problems abound in this area, a subset of which will be addressed as part of the proposed research. The independent variables to be investigated will include the timeliness, quality, quantity, and type of information presented as well as the way in which it is presented; for example, the effects of information contained in reports will be contrasted with the effects of information appearing at a console or on a cathode ray tube display; effects of availability of additional information--e.g., real time access opposed to time-lagged access--on the amount and quality (path) of search will be explored.

1/ See Bellman and Dreyfus [1]. However such examples generally relate to well-structured problems where the goal - e.g., a trajectory - is easily specified.

Earlier research of Gold and Stedry [11] will be extended in the context of the effects of the role of the user of real-time information access on behavior, in an attempt to shed light on appropriate design of information access for different levels in a management hierarchy.

IV. Total Information Systems and Organization Structure and Control

In spite of dire predictions of the impact of the computer on management organization,[1/] few if any major shifts have occurred in the basic organization of the firms using computers. Neither have many fundamental changes occurred in basic techniques, concepts, or organizational relationships established to assign responsibilities or effectuate control over managers or employees within the firm. There are, however, two forces which are beginning to bring about fundamental changes in organizational structure and the points at which control is exercised.

The first of these forces is management science. The insights and operational feasibility it provides towards integrating and rationalizing larger and larger aspects of management operations has altered the way in which many of these operations are performed. (Mixing animal feeds, scheduling oil refineries, controlling inventories, etc.). The second

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1/ For example, see Leavitt and Whistler [18], who predict a complete change in shape from the traditional organization pyramid.

force is the time-sharing, multiple input capability computer. The ability of such a machine to operate in real-time (as we have defined above) permits it to integrate operations which were previously performed under computer control on a separate, although coordinated, basis.

Centralized computers with remote, on-line access will, in themselves, generate considerable pressure on existing organizational structures. It seems likely, however, that an even greater effect will arise from incorporating analytic decision-making models into such an on-line system. For example, rather than organizing control on functions (e.g., selling, transportation, production, inventory management, etc.), such systems will probably lead to integration of functional activities by classes of product or by types of operations performed. This integration will take place irrespective of departmental operations and will cut across traditional operational lines of authority.

The extent to which these integrating pressures will modify traditional operational divisions is not currently predictable. Neither the precise directions, in which organizations will change nor the point at which operational controls will be exercised can be predicted with any degree of confidence. That these controls, and the way in which they are exercised, can produce marked changes in human behavior has been demonstrated by Churchill [9].

Some projections of the effects of total information systems on organizations have been made by Churchill and Stedry [10]. Further

investigation is proposed. A start has been made by examining two operational systems which have been implemented, albeit on a limited scale. This examination will be extended to other installations and conducted in greater depth than the two original studies. The purpose is to develop and test the hypotheses now formed. It is hoped that from the study a clear indication of the patterns of change will emerge and, more importantly, that some normative rules will be developed to aid in the design of organizations involved in real-time, man-machine symbiosis.

V. Information Economics and Technology in Large Scale Electronic Data Processing Systems

The trend in many, large, computer-conscious organizations toward "total information systems" which provide an all-inclusive network for collecting, storing, and processing company-wide data considerably magnifies operating problems in information retrieval. The basic characteristics of a "total information system" include: a very large data base, such as 10^{10} characters, multiple user access and information requirements, and parallel and multi-programmed data processing. Because of the multiplicity of users and large volumes of data handled within these systems, problems in data coding and file organization and maintenance become extremely complex considerations in system design. Similarly, a user request for information which exploits the "total system" capability of the data base may necessitate an

inordinate search of the system and/or several days of data processing computation to provide meaningful answers. As a result, some managers become conditioned to avoid "the system" except in cases of necessity, and in extreme instances to establish a "competing" information system within their own sphere of influence.

Although several "total information systems," particularly in the military,[1/] have been operating during recent years and an increasing number are in various stages of development, few general guidelines have appeared for the design and operation of such systems, e.g., other than the descriptive characteristics mentioned. From the current state of the art it appears that the limiting factor in the development of most of these systems has been the system programming support (software) for the available computer equipment (hardware) configurations. A need exists, therefore, to develop general guidelines for system design and the programming support necessary to cope with information retrieval problems compounded by the concept of the "total system."

To this end, we propose research into the general problem of information retrieval in "total information systems" with particular attention to:

(1) the theory of files and data organization;

(2) data coding and the development of data processing

1/ For example, two early military systems employing many of the characteristics of "total information systems" are the Semi-Automatic Ground Environment (SAGE) system and the Strategic Air Command Control System (SACCS) developed by the U.S. Air Force.

innovations, such as learning programs and "information compilers";

(3) user priorities and system response times; and

(4) system organization and operation.

The investigation will include an empirical analysis of existing "total information systems" and a study of the operating concepts embodied by these systems.

VI. The Design of Programmed Decision and Information Systems

As the potential for modern electronic computers expands within organizations, an increasing amount of decision making is coming to be included within the automation of operating systems. That is, decision making rules are developed and programmed within the system which transform input information on states of the world into output operating decisions. Most research on the development of programmed decision rules, such as the work on aggregate planning problems by Holt, et.al., [12] and Theil [19], has ignored within the formal analysis explicit consideration of the information system which services the organization and processes its input data requirements. Inclusion of information system specifications within the formal analysis of programmed decisions increases the number of alternative decision rule programs considered[1/] and correspondingly the range of performance improvement. To exploit fully developments in

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1/ In general, increasing the number of program alternatives is equivalent to defining complete classes of decision functions, such as discussed by Wald [21] in Chapters 3-5.

computer systems technology through programmed decision making, the economics of both the decisions and information system requirements must be evaluated within the systems analysis.

Research in this area will investigate specifically:

(1) the joint optimization of decision and information system parameters for a variety of operating environments as a means to identifying general criteria for systems design; and

(2) the sensitivity of system behavior and performance to computational efficiency in complex decision rule programs, information accuracy, optimal (i.e., algorithmic) vis-a-vis heuristic formulations, and statistical errors in the estimation of system parameters.

Previous analyses of the first item which will be extended under this study include Kriebel [13] and [17], and Van de Panne [20]. Ongoing research on the sensitivity and feasibility of system designs, such as Kriebel [14] and [16], will also be continued.

Summary

We have presented several problem areas for research resulting from developments in computer technology as they pertain to organizational information systems. This survey does not claim to be exhaustive; rather, it presents a set of areas for research in which the authors and their associates are presently engaged. Furthermore, we have attempted to

define these areas in terms of fruitful research to be carried out by people in academic or quasi-academic organizations. Many kinds of applied research work are more efficiently carried out by people actually working with extant systems and employed by the user organizations. By contrast, if academic research in the information systems area is to be worthwhile, it must go beyond current day-to-day problems faced by people operating and implementing systems.

We wish to reemphasize the long-range nature of the program described. It is directed primarily to the design of systems which will be realized with the "computers of the future". While it is true that current computer technology is well in advance of our knowledge of how to use it, there seems little value in conducting research within such a narrow framework. The real benefits from basic research on information systems would seem to come, rather, from laying the groundwork for use of the computers yet to come, so that management will be prepared to fully capitalize on their potential when they become available.

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13. ABSTRACT

The problem of decision-making and control in response to new information is one which has become increasingly important as developments in electronic computers have increased the quantity of data that can be collected and made possible the collection and processing of this data in "real time." The simple statement that the use of these data, rather than their existence, determines the value of an "information system" seems frequently to be ignored. That is, it is impossible to determine whether or not the existence of more data presented in a more "timely" manner has actually improved operating performance until these data are translated into management actions. Nevertheless pure data collection schemes, are often characterized as "information systems."

This paper outlines a program of research dealing with the expanding capabilities of contemporary and future computers in the context of organizational decision-making, control, and management information system design. The program is long-term. It deals with the description of computerized information systems, their impact on and interaction with the people and organizations associated with them, and prescriptions for the optimal or efficient design of management information systems.

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